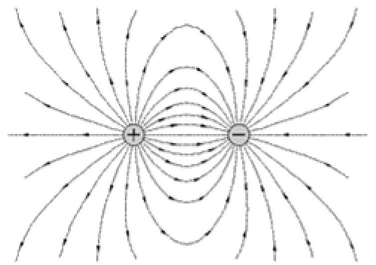
Lesson 2: Ohm's Law: Voltage, Current, & Resistance

Voltage

When electrons are separated from atoms – either through friction (eg, static electricity), chemical reaction (eg, a battery), electromagnetism or other phenomenon – an electrical field is formed, consisting of two oppositely charged terminals, and an associated "tension" or "pressure" between them.

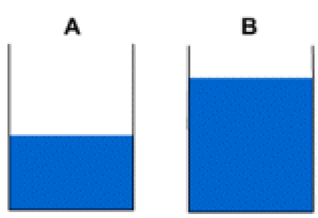


The measure of this "tension" or "pressure" is known as voltage.

Voltage is also known as the difference in electrical potential, since it is a measurement of the potential of the electric field to induce an electric current in a conductive material. In other words, it is the force responsible for "pushing" or "pulling" electrons through a conductive material. Higher voltage results in a more powerful electric current.

If charge is a measure of the amount of electrons, then voltage is a measure of the electrical force that this amount can exert. For example, in a battery, the terminals contain charges (negative and positive), but the actual voltage exists in the space between the terminals.

Mathematically, voltage (V) is electric potential energy per unit charge, measured in joules (0.7376 ft-lbs) per coulomb (6.25×10^{18} electrons), or more commonly, volts. Therefore, a 9V battery can produce 9 joules of energy per coulomb.



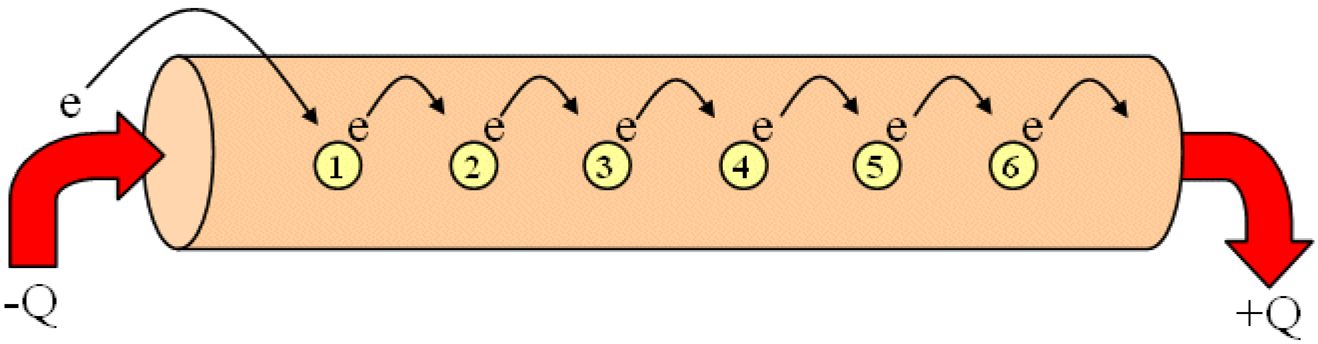
In a hydraulic analogy, voltage is often (loosely) compared to water pressure.

In the diagram on the left, tank B has more pressure than tank A due to the higher water level. In the same way, a 9V battery has a higher "electrical pressure" than a 1.5V battery.

Current

Current is a measure of electrical charge in motion.

Consider a copper wire, connected to the terminals of a battery (-Q and +Q).



Once contact is made between the wire and the battery terminals, electrons from the negatively-charged terminal (on the left) repel the free electrons from the atoms in the copper wire. At the same time, electrons on the right are attracted to the positively-charged terminal. The result is electrical current - a chain-reaction of electrons drifting through the wire.

Mathematically, current (I) is expressed in amperes (A), where

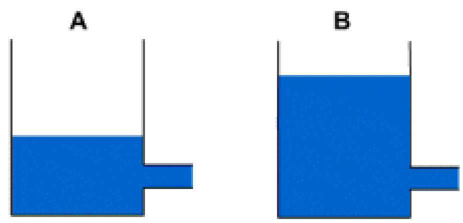
1 ampere = 1 coulomb (6.25 x 10^{18} electrons) per second.

Therefore, a 5A current is more intense, or concentrated, than a 1A current, since there are 5 times more electrons moving per second.

In many electronics applications, electrical current through small circuits is often thousandths or millionths of an ampere. In this case, the following conventions are used:

$$1 \text{ milli-ampere (mA)} = \frac{1}{1{,}000} A = 0.001\text{A}$$

$$1 \text{ micro-ampere } (\mu\text{A}) = \frac{1}{1{,}000{,}000} A = 0.000\ 001\text{A}$$



In a hydraulic analogy, current is often (loosely) compared to flow rate through a hose or faucet.

In the diagram on the left, tank B has more pressure (voltage) than tank A due to the higher water level. As a result, water flows out of the faucet in tank B at a faster rate than tank A.

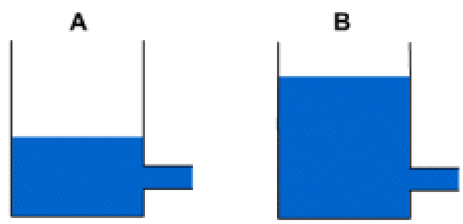
Other factors being equal, an increase in voltage results in a stronger current. Therefore, since a 9V battery has a higher "electrical pressure" than a 1.5V battery, it is capable of generating a stronger current (assuming equal resistance – see next section).

Resistance

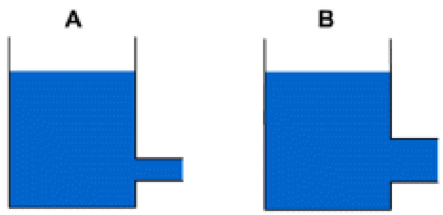
Resistance refers to a material's natural opposition to electrical current. For example, copper has a low resistance; carbon has a much higher resistance. (Resistance, therefore, is the direct opposite of conductivity).

Mathematically, resistance (R) is expressed in ohms (**Ω**).

In a hydraulic analogy, resistance can be (loosely) compared to the size of the hose or faucet.



In the previous example, tanks A and B had the same sized faucet (equal resistance), but different water levels (voltage). This would result in the faster flow of water (current) out of tank B's faucet.



In this example, tanks A and B have equal water levels (voltage); however, the faucet on tank B is larger (less resistance).

The result will be the same – a faster flow of water (current) out of tank B's faucet.

Ohm's Law

From the previous hydraulic analogies, it is clear that current depends on both voltage and resistance. This relationship can be expressed mathematically using Ohm's Law:

$$I = \frac{V}{R}$$

Example

- How much current is produced by a 5V battery through a resistance of 200 Ω ?

$$I = \frac{5}{200} = 0.025A = 25mA$$

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- What will the current be if we increase the voltage to 10V?

$$I = \frac{10}{200} = 0.05A = 50mA$$

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- What will the current be if we decrease the resistance to 100 Ω ?

$$I = \frac{5}{100} = 0.05A = 50mA$$

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Ohm's Law, therefore, clearly shows that proportional increases in voltage (while keeping the resistance constant), or decreases in resistance (while keeping the voltage constant) will result in a corresponding increase in current.